# Radioactive Beam Accumulation in the ESR

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A radioactive $^{56}Ni^{28+}$ was accumulated for the first time in the ESR to an amount usable for a nuclear physics experiment with the ESR internal target. The $^{56}Ni^{28+}$ ions were produced in the fragment separator (FRS) by shooting an intense 600 MeV/u $^{58}Ni^{28+}$ beam from the SIS synchrotron on a fragmentation target. By proper settings of the FRS degrader, contaminants like $^{54}Co^{27+}$ could be reduced to a total fraction of $< 10^{-3}$. Typically $8 \cdot 10^4$ ions were injected at each shot from the SIS. This beam was precooled in two steps (5 s coasting beam + 5 s bunched beam) by stochastic cooling using the newly established time of flight method [1]. The precooled bunched beam was transferred by rf stacking towards an inner orbit of the ESR, where it was neither disturbed by the magnetic field of the injection kicker nor by the rf fields of the stochastic cooling kickers. Here it was gradually moved by electron cooling towards an orbit at a somewhat lower energy. At this orbit, the beam was accumulated using up to 60 injections. The average time between injections was 36 s, as the SIS synchrotron had to serve several different experiments in parallel. Typically $4.8 \cdot 10^6$ secondary $^{56}Ni^{28+}$ ions interacted with the internal target after properly aligning the beam with the (hydrogen or helium) gas jet.

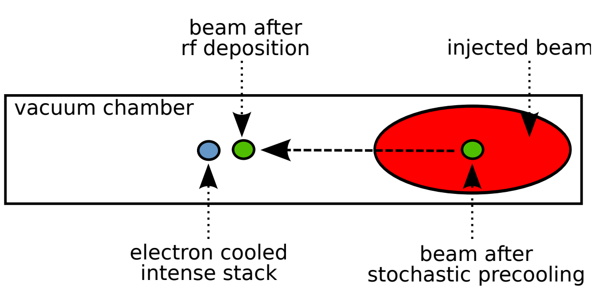


Figure 1: Scheme of beam orbits during accumulation

Fig. 2 shows stochastic precooling of a fresh secondary beam. As long as the beam is coasting the second moment of the momentum width ($\sigma(\delta p/p)$) is decreased by a factor of 3. Due to the non-adiabatic turning on of the rf, $\sigma(\delta p/p)$ increases slightly and is then reduced anew.

Fig. 3 is a waterfall diagram of Schottky spectra ($124^{th}$ harmonic of the revolution frequency) taken just before and after the end of the rf stacking procedure. The distance between stack and deposited beam ($\delta p/p = 4.3 \cdot 10^{-4}$) is chosen such that the two beams are close enough for fast merging by electron cooling without disturbing the stack by the rf. Therefore a low final rf voltage (200 V) was set which corresponds to a full bucket height $(\delta p/p)_{max} = 3.9 \cdot 10^{-4}$.

Fig. 4 displays a series of measured data points from the DC beam current transformer. Although its resolution is limited, the data points are rather linear, indicating that the stacking procedure is working practically lossless.

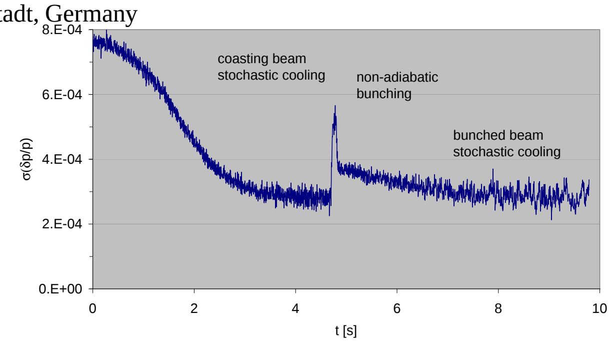


Figure 2: Momentum cooling of freshly injected beam

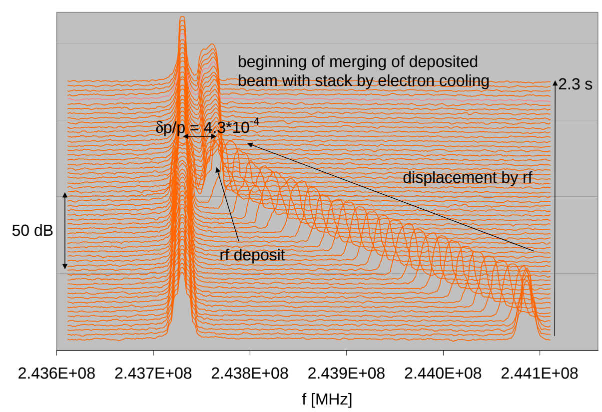


Figure 3: Schottky spectra around beam deposit (see text)

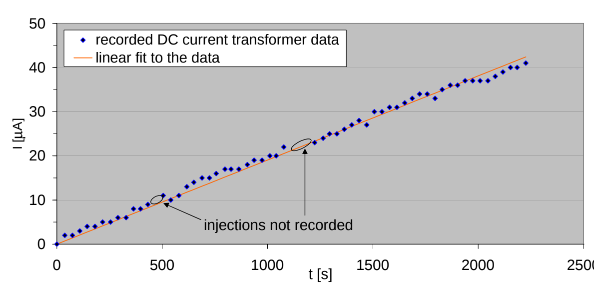


Figure 4: DC beam current transformer data as a function of time

## References

[1] C. Dimopoulou et al., this report